Origin of clinopyroxene-ilmenite symplectites in mafic granulites from eastern parts of the Chotanagpur granite gneissic complex, East Indian shield

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Abstract

In this manuscript, we report a rare occurrence of rod-like intergrowths of clinopyroxene-ilmenite that variably replace titanite in a suite of high-pressure mafic granulites from the Chotanagpur Granite Gneissic Complex, Eastern Indian Shield. Garnet proximal to the clinopyroxene-ilmenite intergrowth is invariably replaced with symplectic clinopyroxene-plagioclase or a ring of plagioclase. Textural modeling of the reaction textures and mineral compositions suggests that the garnet-titanite became unstable and the ilmenite-clinopyroxene preferentially develop after titanite. The presence and texture of halogen rich apatites within the ilmenite-clinopyroxene symplectite are consistent with a fluid mediated process. Thermodynamic modeling in the NCFMAST (+H2O) system, demonstrates that the clinopyroxene-ilmenite symplectite was formed along a steeply decompressive retrograde P-T path (from ~13 to ~7 kbar, at ~800 °C), in the presence of partial melts. The study demonstrates that relative to Fe, Mg, and Ca, Ti was less mobile and that the mobility of Ti was restricted within the confines of titanite being replaced by the clinopyroxene-ilmenite symplectite. This study implies that besides the ligand activity, the fluid/rock ratio exerts a strong control on the length scale of Ti transport in natural rocks.

Keywords: Clinopyroxene-ilmenite symplectite, high-pressure metamorphism, CGGC, textural modeling, CSpace, XmapTools, Ti mobility

Introduction

Symplectic intergrowths of clinopyroxene and ilmenite are quite rare in metamorphic rocks. Clinopyroxene-ilmenite symplectites have been reported from mantle xenoliths of deep origin, kimberlites, and other alkaline rocks (Nixon and Boyd 1979; Garrison and Taylor 1981; Litasov et al. 2003; Ashechepkov et al. 2014 and references therein), where their origin is explained either by exsolution from high-pressure garnet (Ringwood and Lovering 1970) or clinopyroxene (Dawson and Reid 1970), or by cotectic or eutectic co-precipitation from a protokimberlite melt (Nixon and Boyd 1979; Garrison and Taylor 1981; Litasov et al. 2003).

But in metamorphic rocks formation of clinopyroxene-ilmenite symplectites is even rarer, and its occurrence is mainly restricted to high-pressure metamorphic rocks such as HP basic granulites and retrogressed eclogites (O’Brien and Rötzler 2003; Zhang et al. 2003; Faryad et al. 2006; Marsh and Kelly 2017). Depending upon bulk rock compositions and the ambient physiochemical conditions, metasomatic rocks contain one or more of the accessory phases, like titanite, rutile, and ilmenite that chiefly contribute to the Ti-budget of the metasomatic rocks. Experimental studies have shown that the solubility of Ti in pure H2O is very low over a range of pressure and temperature (nominal soluble, Purtov and KoteVnikova 1993; Ryzenko et al. 2006; Antignano and Manning 2008; Rapp et al. 2010; Hayden and Manning 2011; Tanis et al. 2016; Karmakar 2021). However, the solubility of Ti is dramatically enhanced in presence of halogen-rich, particularly F-rich fluid (Rapp et al.2010). The experimental data suggest, therefore, different length scales of transport of Ti in crustal rocks depending on the physical conditions and the composition of the transporting media (Antignano and Manning 2008; Rapp et al. 2010; Hayden and Manning 2011). Because rutile, titanite, and ilmenite are the main Ti-sink of metasomatic rocks, an understanding of the relative stability of the three Ti-rich phases put important constraints on the behavior of Ti during the evolution of metasomatic rocks. Titanium (and other HFSEs) is commonly used as a fixed reference frame for mass-balance calculations and geochemical interpretations in metamorphic and metasomatic processes (Ague 2011). This approach may be seriously affected if Ti becomes significantly mobile.

In this communication, we document an occurrence of a clinopyroxene-ilmenite symplectite that grew after titanite in a suite of high-pressure high-temperature mafic granulites from the Chotanagpur Granite Gneissic Complex (CGGC), Eastern Indian Shield (Fig. 1a). Our study demonstrates that the clinopyroxene-ilmenite symplectite was formed due to the instability of garnet and titanite when the rock evolved along a steeply decompressive P-T path. Despite the presence of halogen-bearing fluid, the length scale of movement of Ti is restricted to a few tens of micrometers in length. The likely mechanism of